THE JOURNAL

OF THE

ROYAL AERONAUTICAL SOCIETY

(FOUNDED 1897 in succession to the ANNUAL REPORTS)

Edited for the Council by J. LAURENCE PRITCHARD, Fellow

No. 171 MARCH, 1925 VOL. XXIX

NOTICES

Elections

The following Members were elected at a Council Meeting held on February 10th :—

Associate Fellows.—Major H. Hemming and Mr. G. Lyon.

Foreign Member.—Mr. W. A. Yackey.

Scottish Branch.

Member.—Mr. W. Ramsey.

Silver Medal

The Council have awarded the Society's Silver Medal for the year 1924 to Major W. S. Tucker, D.Sc., A.M.I.E.E., for his paper on "Sound Reception," which appeared in the issue of the Journal for August, 1924.

Annual General Meeting

The Annual General Meeting will be held in the Library on Tuesday, March 31st, at 5.0 p.m. The Statement of Accounts for the year ending December 31st, 1924, and Council's Annual Report will be found elsewhere in this issue.

Notice of any subject to be brought up for discussion at the Meeting must be received by the Secretary not later than March 17th. Nominations for election to the vacancies on the Council signed by two voters, and accompanied by a statement signed by the Candidate signifying his willingness to serve if elected, must be received by the Secretary not later than March 10th. The following Members of Council are due to retire and are eligible for re-election :—Professor L. Bairstow, Wing Commander T. R. Cave-Browne-Cave, Sir Mackenzie Chalmers, Mr. C. R. Fairey, Lieut.-Colonel J. T. C. Moore-Brabazon, Lieut.-Colonel M. O'Gorman, Mr. J. L. Pritchard, Colonel the Master of Sempill, Major R. V. Southwell, and Lieut.-Colonel H. T. Tizard.

Wilbur Wright Lecture

The Thirteenth Wilbur Wright Memorial Lecture will take place on Thursday, April 30th, at 8.30 p.m. Rear-Admiral D. W. Taylor, U.S.N., D.Eng., Secretary of the Executive Committee of the National Advisory Committee for Aeronautics, has accepted the invitation of the Council to deliver the Lecture, and will read a paper on "Some Aspects of the Comparison of Model and Full-Scale Tests."

Postponed Lecture

Colonel F. Searle's postponed lecture on "The Maintenance of Commercial Aircraft" will be held in the Library at 5.30 p.m. on Thursday, April 23rd.

Library

The following books have recently been received and placed in the Library :— "Per Ardua ad Astra," "110908"; "Makers of Science," I. B. Hart; "The German Air Force in the Great War," G. P. Neumann; "Das Leichtflugzeug," W. von Langsdorff; "The Guardian," Vol. II.; "Technical Report of the Advisory Committee for Aronautics 1920-21" [2 Vols.]; "Fifth Annual Report of the National Advisory Committee for Aeronautics [U.S.A.] 1919;" and "Handbook of Strength Calculations," Air Ministry.

Forthcoming Arrangements

Thursday, March 5th, 5.30 p.m.—In the Library. Lieut.-Colonel C. B. Heald, "Some Medical Aspects of Air Transport."

Tuesday, March 10th, 5.30 p.m.—Council Meeting.

Thursday, March 19th, 5.30 p.m.—In the Library. Captain F. Tymms, "Practical Navigation of Aircraft."

Thursday, March 26th, 5.30 p.m.—**At the Royal Society of Arts.** Dr. Eckener, "Modern Zeppelin Airships."

Tuesday, March 31st, 5.0 p.m.—Annual General Meeting.

W. Lockwood Marsh, *Secretary.*

The Council have to announce that they have received Colonel Lockwood Marsh's resignation of the position of Secretary. After full consideration they feel that they have no option but to accept his resignation with very great regret.

ROYAL AERONAUTICAL SOCIETY

60TH ANNUAL REPORT OF THE COUNCIL, 1924-1925.

Council

Chairman: Lieutenant-Colonel H. T. Tizard, A.F.C.

Vice-Chairman: Lieutenant-Colonel A. Ogilvie, C.B.E.

Professor L. Bairstow, C.B.E., F.R.S., Major-General Sir W. S. Brancker, K.C.B., A.F.C., Mr. Griffith Brewer, Wing Commander T. R. Cave-Browne-Cave, C.B.E., Sir Mackenzie D. Chalmers, K.C.B., C.S.I., Mr. C. R. Fairey, Professor C. F. Jenkin, C.B.E., Major A. R. Low, Mr. W. O. Manning, Lieutenant-Colonel J. T. C. Moore-Brabazon, M.C., M.P., Mr. J. D. North, Lieutenant-Colonel M. O'Gorman, C.B., Mr. J. L. Pritchard, Colonel the Master of Sempill, A.F.C., Sir Napier Shaw, F.R.S., Major R. V. Southwell, Major H. E. Wimperis, Mr. R. McKinnon Wood.

Hon. Treasurer: Mr. A. E. Turner.

Hon. Librarian: Mr. J. E. Hodgson.

Editor: Mr. J. L. Pritchard, F.R.Ae.S.

Membership

The following table of the Membership position on January 1st, 1925, has been prepared in a new form showing the state of each grade:—

Grade.	No. of Members.	Hon. and Life Members.	Suspended.	Totals.
Fellows	56	13	2	71
Associate Fellows ...	265	8	20	293
Students	84	—	18	103
Members	61	15	9	85
Associate Members ...	60	1	4	65
Founder Members ...	52	—	1	53
Foreign Members ...	27	24	7	58
Scottish Branch ...	51	—	39	90
	656	61	100	817

Library

The Council desire to thank Mr. J. E. Hodgson, the Honorary Librarian, for the time he has devoted to the Library during the year, resulting in a complete re-arrangement of the books and a fresh card index, which has very considerably increased its value and interest. Mr. Hodgson has incorporated in his recently published book, "The History of Aeronautics in Great Britain," a considerable amount of interesting details of the early history of the Society and its founders, including a list of the important papers published in the "Annual Reports" between the years 1866 and 1893.

A number of books have been added to the shelves during the year, mainly of copies supplied for review in the Journal and presented by newly-elected technical members in lieu of theses.

Awards

The Silver Medal of the Society, given annually for the paper considered by the Council to be the best published in the Journal each year, was awarded for the year 1923 to Squadron Leader R. M. Hill, M.C., A.F.C., A.F.R.Ae.S., R.A.F., for his paper on "The Manœuvres of Inverted Flight," and for the year 1924 to Major W. S. Tucker, D.Sc., A.M.I.E.E., for his paper on "Sound Reception."

The Council awarded the R.38 Memorial Prize, 1924, to the paper on "The Strength of Rigid Airships," by C. P. Burgess, J. C. Hunsaker and S. Truscott, which had received special mention in 1923.

Associate Fellowship Examination

The third examination for Associate Fellowship was held in the Library on September 23rd, when three candidates were successful. The papers set were published in the issue of the Journal for October, 1924.

Institution of Aeronautical Engineers

Negotiations have been proceeding with the Institution of Aeronautical Engineers which will, it is hoped, lead to a very desirable amalgamation between the two bodies. When the terms are agreed upon between the two Councils they will be laid before the members for ratification, a Special General Meeting being called for this purpose.

Journal

The Council are able to record a continued improvement in the circulation of the Journal to persons outside the membership of the Society, the number of annual subscriptions having increased by a further 25 per cent. during the year.

The Council feel that the Society is greatly indebted to Mr. Pritchard for the high technical standard maintained by the Journal as a result of his efforts. Mr. Pritchard has again generously remitted his fees as Editor.

Lectures

The Twelfth Wilbur Wright Memorial Lecture was delivered on May 29th, 1924, when Lieutenant-Colonel H. T. Tizard, A.F.C., read a paper on "Fuel Economy in Flight."

The full programme of Lectures during the present Session is as follows:—

1924.

Oct. 2nd.—Lieut.-Colonel H. T. Tizard, "Common Sense and Aeronautics."

Oct. 16th.—Dr. Rohrbach, "Large All-Metal Seaplanes."

Oct. 30th.—Major J. S. Buchanan, "The R.Ae.C. Light Aeroplane Competitions."

Nov. 13th.—Professor L. Bairstow, "Skin Friction."

Nov. 27th.—Dr. G. C. Simpson, "Thunderstorms."

Dec. 18th.—Mr. R. A. Watson Watt, "Recent Studies on Radiotelegraphic Atmospherics."

1925.

Jan. 22nd.—Major R. V. Southwell, "Some Recent Work of the Aerodynamics Department, National Physical Laboratory."

Feb. 5th.—Air Commodore C. R. Samson, "The Operation of Flying Boats in the Mediterranean."

Feb. 19th.—Lieut.-Colonel L. F. R. Fell, "Light Aeroplane Engine Development."

Mar. 5th.—Lieut.-Colonel C. B. Heald, "Some Medical Aspects of Air Transport."

Mar. 19th.—Capt. F. Tymms, "Practical Navigation of Aircraft."

Mar. 20th.—Dr. Eckener, "Modern Zeppelin Airships."

April 23rd.—Colonel F. Searle, "The Maintenance of Commercial Aircraft."

Finance

The Council have again to report an excess of expenditure over income for the year. Except during the war period, the Society has never found its income (apart from special donations) sufficient to balance the expenditure.

The Council has given serious consideration to the position, and has effected certain economies and made other arrangements which they anticipate will result in an improved state of affairs during the coming financial year.

Honorary Treasurer

The Council desire again to express their appreciation of the advice and assistance received from Mr. A. E. Turner, who has continued to act as Honorary Treasurer.

Staff

The Council have pleasure in recording their great appreciation of the services of the Staff, which has remained unchanged during the year.

AERIAL SCIENCE, LIMITED

Balance Sheet,

Dr.	£ s. d.	£ s. d.
To *Nominal Capital*—		
Divided into 20 Shares of 1/- each and 999 Shares of £1 each ...	1000 0 0	
,, *Capital Issued and Paid Up*—		
19 Shares of 1/- each		0 19 0
,, *Sundry Creditors*		1267 5 1
,, *Subscriptions Received in Advance*		35 2 0
,, *Carnegie U.K. Trust Grant*—		
For Purchase of Books		500 0 0
Expended to 31st December, 1923	455 16 8	
,, during 1924	9 11 11	
	465 8 7	
,, *Reserve Fund*—		
Entrance Fees and Life Compositions of present Members, as at 31st December, 1923	2681 9 0	
Receipts for year to 31st December, 1924	69 5 0	
	2750 14 0	
Deduct—Income and Expenditure Account Deficiency at 31st December, 1923 ... ... £1823 4 4		
Add—Excess of Expenditure over Income for the year to 31st December, 1924 ... ... 358 16 10		
	2182 1 2	
		568 12 10
		2371 18 11
,, *Special Funds*—		
Balance at Bank *as per contra*		142 14 4
		£2514 13 3

We report to the Shareholders that we have examined the books of the Society and have of the value put upon the outstanding subscriptions. Subject to this remark, we are of opinion of the Society's affairs according to the best of our information and the explanations given to us

3, FREDERICK'S PLACE, OLD JEWRY, E.C.2.
2nd February, 1925.

Income and Expenditure Account (excluding Special

Dr.	£ s. d.
To Office Rental, Lighting and Insurance	350 2 1
,, Salaries	1058 18 9
,, Printing and Stationery	65 6 7
,, Postage and Messengers	66 15 10
,, Library Expenses	4 4 11
,, Office Expenses	51 6 4
,, Exhibitions and General Meetings	90 4 4
,, Journals, Pamphlets, Etc.	511 0 1
,, Audit Fee	10 10 0
,, Subscriptions Written Off	66 2 3
,, House Duty	16 11 6
,, Medals...	9 19 6
	£2275 2 2

Journal and Sundry Publications

	£ s. d.
To Stock, 31st December, 1923...	429 16 1
,, Sundry Debtors	98 1 11
,, Law Costs *re* Advertising	2 2 0
,, Refunds	7 0 11
,, Printing of Journal	908 14 6
,, Postage of Journal	68 0 7
,, Binding of Journal	9 5 0
,, Blocks for Journal	167 5 0
,, Printing of Advance Proofs...	56 2 6
,, Printing of Reprints...	2 15 6
	£1749 4 0

(The Royal Aeronautical Society).

31st December, 1924.

Cr.	£ s. d.	£ s. d.
By *Office Furniture, Printed Books, Bindings, Stationery, Old Prints, etc.*, as at 31st December, 1923 (including Carnegie Grant—£455 16s. 8d)	786 13 4	
Add—Purchases during year—		
Furniture	6 18 3	
Books	9 11 11	
	16 10 2	
		803 3 6
,, *Stock of* JOURNALS, *etc.*		454 8 3
,, *Stock of Stationery*...		16 1 0
,, *Sundry Debtors, including Subscriptions owing*		199 5 4
,, *Investments at Cost*—		
£783 6s. 0d. 5% War Stock (Inscribed), 1929/47		725 13 6
,, *Cash at Bank and in Hand*—		
At Bank	166 16 2	
In Hand	6 11 2	
	173 7 4	
		2371 18 11
,, *Cash at Bank for Special Funds*		142 14 4
		£2514 13 3

obtained all the information and explanations we have required. We are not in a position to judge that such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state and as shown by the books of the Society.

(Signed) PRICE, WATERHOUSE & CO.

Funds) for the Year Ending 31st December, 1924.

Cr.	£ s. d.
By Annual Subscriptions	1867 3 2
,, Interest on Investments	44 3 2
,, Profit on Sale of National War Bond	3 3 0
,, Examination Fees 12 12 0	
Less Expenses of Examinations 10 13 0	
	1 19 0
,, Balance, being Excess of Expenditure over Income	358 16 10
	£2275 2 2

Trading Account (Secretary's Statement).

	£ s. d.
By Sale of Journals	542 16 1
,, Advertising Revenue	183 7 3
,, Sale of Journal Cases	7 8 0
,, ,, Advance Proofs	9 2 0
,, ,, Sundry Publications	41 2 4
,, Stock, 31st December, 1924	454 8 3
,, Balance, loss carried to Income and Expenditure Account	511 0 1
	£1749 4 0

PROCEEDINGS

Second Meeting, Second Half, 60th Session.

A meeting of the Royal Aeronautical Society was held in the Society's Library, at 7, Albemarle Street, London, on Thursday, February 5th, 1925, when a paper on "The Operation of Flying Boats in the Mediterranean" was read by Air Commodore C. R. Samson, C.M.G., D.S.O., A.F.C., Associate Fellow. Lieutenant-Colonel H. T. Tizard, A.F.C. (Chairman of the Society), presided.

THE OPERATION OF FLYING BOATS IN THE MEDITERRANEAN

BY AIR COMMODORE C. R. SAMSON.

It is with some diffidence that I give this lecture in front of such a critical audience. I did not suggest the lecture myself; but I was asked if I could give it. It is, I am afraid, rather ancient history, dealing as it does with the years 1921-22. Since the beginning of 1923 I have had no seaplane experience, so I cannot judge as to whether some of the things we found out have been useful or otherwise. All I can say is that we ourselves discovered a good lot and were all greatly astonished at what an old "F.2 A." could stand.

I had better start with a brief description of the flights we made; but before I do so it would be advisable to explain why we did them and what we had to do them with.

In the autumn of 1921 I was sent out to command the R.A.F. Mediterranean. This consisted of a headquarters at Malta, a seaplane station at Calafrana, Malta, a seaplane station at Feneraki, Constantinople, and H.M.S. "Pegasus," a seaplane carrier.

At Calafrana there were five "F.2 A.'s" and one "F.3," also two or three Fairey "3 C.'s."

At Feneraki there were four Fairey "3 C.'s."

Aboard H.M.S. "Pegasus" there were five Fairey "3 C.'s."

I found that very little flying was carried out with the "F.2 A.'s," all the flights that were made were purely local ones, although in 1919 and early in 1920 some longer flights had been made. The latter part of 1920 and all 1921 had been very lean years. There were only two first boat pilots. The squadron at Calafrana was not organised in flights and no boat had a crew.

The "F.2 A.'s" were all veterans built in 1918. They did not look in very good condition.

I soon discovered that the same performances could not be expected from these flying boats as we obtained at Yarmouth and Felixstowe during the war. The planes themselves were not in the same condition, due to climatic changes. The hulls were porous and the same lift could not be obtained out of the air. At home we used to take "F.2 A.'s" off the water with crews of five and six, four or five guns and 320 gallons of petrol. Before I go any further I may here give my reasons for carrying out the flights we did.

(1) To train the command for war.

(2) To gain experience in seamanship, navigation and local reconnaissance.

(3) To give pilots a knowledge of the Mediterranean, its climate and strategic points.

(4) To prove to foreign Powers and our diplomatic representatives that the R.A.F. was an active and efficient service.

(5) To gain experience of the behaviour of flying boats in all types of weather on detached service.

I received every encouragement and assistance from H.E. Field-Marshal Lord Plumer and the two Naval Commanders-in-Chief, Sir John de Robeck and Sir Osmond de B. Brock. In addition, Mr. Sarel, the British Consul-General at Tunis, was an old friend of the R.N.A.S. during the war.

The first difficulty to be overcome was to obtain permission to visit a foreign port. This seems a simple operation, but I can assure you that at first I had endless trouble; after two or three flights I got everything working very well, and we could obtain the required permission within 48 hours. There was also a slight opposition from home that had to be overcome. Personally, I was in a fairly fortunate position. I had undergone a good deal of experience with "F.2 A.'s" during 1918 at Yarmouth and Felixstowe, as well as many hundreds of hours on float seaplanes in various parts of the world. In addition, I have spent many weeks living in an open boat chasing gun-runners in the Persian Gulf.

I started with three main ideas:—

(A) The boats were to be self-contained.

(B) The crews were to live in the boats.

(C) That once we fixed a day to start anywhere we would go regardless of weather.

The Mediterranean, to those who only see it from the deck of a liner, is popularly supposed to be always like a mill-pond. Personally, after seven years' experience of it in all types of vessels, floating and flying, I cannot agree with this. You can get it as rough as you want it at any time of the year. Try the Southern Adriatic in a "Bora." Fly between Corsica and Sardinia, or along the Western Greek coast with a north-easterly wind blowing, or the Malta Channel with a "Gregali" in full force. Try and get off the water in a heavily laden "F.2 A." at Oran between 10 a.m. and 4 p.m. Go yachting off Cape Fegalo. Fly a seaplane at Gibraltar. You will get all the weather you want. The sea gets up very quickly in the Mediterranean; luckily it goes down just as rapidly.

There were three main flights to be done:—

(1) To Feneraki, near Constantinople, to inspect the flight stationed there.

(2) To Gibraltar.

(3) To Alexandria.

Although I realised that we were trying to run before we could walk, I decided to start off for Constantinople before we did any shorter journeys. I felt that we could learn very much more by attempting to do this than by trying anything shorter.

I decided that the best winter route was via Corfu and Athens. If we went via Matchpan it provided us with a very long trip which might entail us running out of petrol in case of a head wind.

Corfu was about 350 sea miles, or 6½ to 7 hours. There was a British Consul there and a good harbour. I calculated we should get to Athens before dark and reach Feneraki about mid-day on the following day.

The following were the re-fuelling arrangements:—300 gallons of petrol and 40 gallons of oil were left at Corfu by a British destroyer in charge of the Consul. I wrote to the Consul asking him to arrange to bring the fuel off in a boat as soon as we alighted. The petrol was in 4-gallon tins. At Athens the Consul-General was asked to arrange for fuel to be provided at Phalerun Bay, the Greek naval seaplane station.

The equipment of the boats needed considerable consideration.

The service equipment was absurd—it consisted of a wire mooring pendant attached to a shackle bolted to the keel. It was obvious that this shackle would be torn out after a minute or two. The first thing to be wanted was a Yarmouth strop—a two-legged strop designed by myself whilst at Yarmouth. It consisted of two legs shackled to the roots of the engine bearer struts and meeting at a ring, to which a towing or mooring line could be attached. Unfortunately none were on charge at Malta and they had to be made, but were not ready in time. The anchor was too absurd for words and it is doubtful if it would hold a dinghy, much less a "F.2 A." even in a calm. Still it was the best available. In addition I took a good grapnel we picked up in the dockyard.

The scarff ring was removed from the bows and a bollard was placed there; also two cleats. Three heaving lines were coiled down in the bows and two mooring lines—each about 30 fathoms—used as cable for the anchor and grapnel. One large petrol funnel, two chamois leathers, two engine covers which I had ordered to be made out of fabric, but which I found were made of heavy canvas, which weighed tons; engineer's tool kit, spare cylinder complete, four valves, 24 sparking plugs, magneto, starting magneto, rubber tubing, copper piping, fabric, acetone, twine, etc., Aldis lamp, Very pistol and 36 lights, Lewis gun and four chargers, one hand lantern with candles.

W.T.—I found out afterwards that the W.T. operator had smuggled on board a spare set of accumulators.

Emergency rations for six days:—Four gallons of drinking water, medical box, food for three days, two thermos flasks filled with coffee.

I ordered that everybody was to take a complete change of underclothing, spare suit, Sidcot suit and lifebelt.

Charts and sailing directions.

The crew consisted of Flying Officer Carnegie, first pilot; myself, second pilot; Squadron-Leader Gordon, observer; an engineer; a W.T. operator.

We started off at 4.45 a.m. and left the water with 280 gallons of petrol—about the best load we ever carried. We had quite a good trip until halfway between the Italian coast and Corfu, when the port engine began to pan out. I decided that we had better try and make the Italian coast; we therefore headed for it, but after keeping up for ten minutes we could not go on any longer and had to alight on a really nasty sea. I thought it even money on our bottom going, but Carnegie just hit it off right, and we got slowed down before a real grandfather of a wave got us. It drenched us properly. If we had landed half a second later, we would have just about got him and been stove in for certain. We had been in the air for five hours and a quarter.

The coast was about 30 miles off, no ships in sight, a real nasty sea running, and the engineer reported only 20 gallons of petrol left. The port engine stopped. We kept the starboard engine going and a drogue out to keep her head to sea. It was really unpleasant as we were taking in seas as well as a constant stream of spray. The only thing to do was to taxy on as far as we could on the fuel. We got the port engine going for about two or three minutes at a time; sometimes it would run for five minutes. If we taxied too fast we got a bad time as the hull hammered like anything and we got drenched; if we

went too slow we could not steer and the engine would stop without having done us any good. The beach never seemed to get any closer, as after we had made a mile or two the port engine would stop and we would drift out as far as we had gained. It certainly appeared that we would never reach the shore before the fuel ran out and that we would then drift gaily back down the Adriatic. Luckily, however, the wind and sea dropped a little and the port engine kept going for longer periods, so that we eventually got into Santa Maria di Lucca.

We borrowed an anchor from a shore boat and moored up the boat securely, then got off a telegram to Malta asking for a towing lighter to be sent to take us back. The lower plane was fairly badly damaged. We spent two days at the place, until a destroyer arrived—without a towing lighter. We therefore had to make the best of things and tow the boat. I did not fancy it very much as the weather was none too good. We secured a grass hawser round the roots of the engine struts and also used the towing strop, adjusting the length of tow to about ten fathoms—which put us on the crest of the second stern wave. The towing strop soon carried away from the keel.

We reached Malta all right, with little further damage to the boat, but we had some anxious moments. The weather was pretty rough the whole time and the "F.2 A." danced about and yawed pretty severely. It was very uncomfortable on board her; we took turns at it, but after six hours of it I was pretty well knocked out, as I was feeling rather ill—the result of our good soaking when we came down. As a matter of fact, when I got to Malta I went to bed with a temperature of 106°. The boat was ready for flight within 48 hours of our return. We never discovered what was the seat of trouble in the port engine.

Flight No. 2 was to Constantinople. This time it proved successful. We took a crew of four—Carnegie, myself, Sergeant Whitfield, W.T. operator and L.A.C. Trevelyan, engineer.

We started at 5 a.m., on December the 5th, with a wind on the port bow at first. We arrived safely at Corfu, after six hours and 40 minutes, 320 nautical miles. Arriving at Corfu we found a big sea running, so we alighted under the lee of a small island off the town. Taxying into the little harbour we inquired where the petrol was, as we expected a boat to come off with it. We were informed that it was in a shed under the citadel, and if we would go to the big mooring buoy they would bring it off in a boat. We picked up this buoy, which was an enormous fellow, and patiently awaited in the pouring rain. The sea was pretty rough; but we did not mind as we felt we had broken the back of the journey. At last a boat arrived with the British Consul himself, but no petrol. I am afraid I was a little terse and said we were in a hurry. He then understood. We had a bit of a job getting the fuel in as there was a big sea and the Greek crew were enthusiastic. We also lacked the experience which we obtained later. Luckily we took aboard some four-gallon tins. By the time we were finished it was getting pretty near sunset, but I decided it was better to push off. We got off all right and set off down the Greek coast, soon running into a bad time—thunderstorms around us and over us, and some of the most colossal bumps I had had for many a day. A nasty sea was running below us and it was pitch dark. The only thing to do was to alight, so we went on until I saw what looked a likely spot in the Santa Maria Channel. We got down all right and found ourselves in a lagoon with only about three feet of water in it. We let go all anchors and waited for the dawn. It rained torrents all night; but we kept partly dry—a Sidcot suit keeps out a lot. The morning broke pretty beastly, so we waited until 10 a.m. before we started off. We had a good trip to Athens; arriving over Phaleron seaplane station, we found it dangerous to alight there as there was a big sea running and no hope of refuelling without big risk of damage. So we made for the Piræus and alighted inside the breakwater, secured to a convenient buoy and awaited events. These came in the

shape of a Greek naval aviation officer. They sent the fuel round—it was in 50-gallon drums, the very devil to open and the very devil to handle. Here was where our 4-gallon tins came in handy. We got it in all right after much labour, but we did not have enough. We finally got what we wanted by 1 a.m. Next morning we had a terrible job to get off the water. We had lost a lot of fabric off one of our propellers, due to rain between Corfu and Santa Maria; finally we had to cut the whole fabric off this propeller. The boat was leaking badly and we had to pump out a lot of fuel. We spent no less than 3½ hours trying to get off; there was not a spot of wind to help us. Finally, just as we had given up hope, she got on to her step and off we went to Constantinople.

We had an uneventful trip, alighting at Chanak for five minutes to talk to a destroyer there. We had a bit of rain and low clouds, but did not mind much as we were nearing our objective. We arrived over Feneraki after a six hours' trip with about two gallons of fuel left, having done the trip across the Marmora at three feet. We stayed all the next day at Feneraki, where we had the boat pumped out and the fabric removed from the other propeller. The day after we set off on the return journey. It took us the usual two hours to get off, although we had two Faireys to make a wash and wind for us, and we had to get rid of some petrol again. Reaching Athens we had some trouble in getting our petrol; it was again about 1 a.m. before we had finished. Next morning we flew to Corfu finding a big sea running there. We alighted to leeward of the citadel and taxied close up to the shore in shoal water. We moored her head and stern by the aid of our anchors and one we borrowed. Finding that the petrol we had left at Corfu was insufficient for us, we had to get some motor spirit. It was the most filthy, evil-smelling stuff I have ever seen. We put in 60 gallons of it and hoped for the best. As it was getting late and half a gale was blowing I decided to remain for the night. That night was the most uncomfortable one I have spent in a boat. My body found every excrescence in the boat there was to be found, and it was so cold it was impossible to sleep. We were saved in the morning by the arrival of a boatman with some hot coffee. When I had got a couple of cups of that inside me the whole outlook was changed. The boatman towed us out stern first and we started off. We got off like a flea as there was a big sea running; the quickest ascent we had ever made. We flew across the island and found a full gale blowing in the Adriatic—a horrible looking sea running and low clouds; visibility about 400 yards. We soon found our drift was about 60°. I know for one that I was never so glad to see anything as I was to see the Italian coast, which we did after two and a quarter hours—the rest of the journey was top-hole; a good old Bora behind us and doing 90 knots throttled well down. We did not care what petrol we had although the smell of the Corfu stuff was awful; still it did its job well. Forty miles from Malta we met end on a "F.2 A." sent out to escort us in. We alighted at Calafrana (Malta) happy men after 32 hours and 7 minutes in the air and 1,900 nautical miles.

The boat was ready for flight within 24 hours. We had learnt a tremendous lot from this flight. First and foremost I said, "Never again without a stove of some sort to make hot drinks and we must have better sleeping accommodation." We had shown that the boat was absolutely self-contained and needed no outside assistance.

The following new fittings were made and fitted to the boat:—

(1) A better type mooring bollard with a belaying pin.

(2) Light hollow wooden reels for mooring lines were fitted in the boat's cockpit. Thus all our tackle was kept free of turns and kinks and out of the way.

(3) Yarmouth strop was carried.

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(4) A cover was made for the front cockpit.

(5) Light-weight engine covers were made.

(6) A petrol funnel with long length of rubber tubing with a band to hold the chamois leather. Slings were attached to the funnel, the other ends of the slings were fitted with hooks so that the petrol funnel was held up without manual labour.

(7) A Primus stove was carried and cooking was carried out inside a petrol can. Experiments were started to cook by means of exhaust or by electricity, but were abandoned owing to the extra weight required.

Two bunks were constructed. These bunks were made of wood and Willesden canvas and were extremely light. They were hinged and when not in use clipped up against the side of the tail. Each bunk had a fabric sleeping bag attached to it.

Better pumping out arrangements were absolutely essential. The semi-rotary pump was too inefficient as it was always getting choked up. The best method was discovered to be a large garden syringe.

Flight No. 3 was made to Bizerta in order to see what refuelling arrangements could be made there for a flight to Gibraltar. As a matter of fact the Gibraltar flight had to be temporarily postponed owing to various circumstances.

Flight No. 4 was made to Naples. The crew had an uncomfortable time on this flight due to the constant rain.

Flights No. 5 *and No.* 6 were made with two boats to Bizerta, one went to Tunis on the way back. These flights were uneventful—beautiful calm weather, but were useful to train crews.

Flight No. 7 to Palermo. They had bad weather the whole time.

Flight No. 8 to Tripoli (Africa). This flight was interesting as the boat was navigated by sextant observations. A perfect landing was made both ways. They had a stormy return journey and I was glad to see them arrive.

Flight No. 9 was to Athens and back via Corfu. A crew of five was taken—Flight-Lieut. Stewart, F.O. Hackney and Clift.

They had a good trip as far as Corfu, where they refuelled, then they ran into very bad weather. heavy rain and hailstorms and a 40-knot wind. After flying for two hours conditions became so bad that they alighted at Misselonghi Lake.

From Misselonghi to Athens conditions were good.

They left Athens on fifth day and had a good trip to Corfu.

On the sixth day a start was made from Corfu. They ran into appalling weather across the Adriatic, a head wind of 40 knots being encountered. They came down in Sicily out of petrol, finally returning on the eighth day to Malta.

Flights Nos. 10 *and* 11 were intended to be to Palermo. They encountered bad weather off the Sicilian coast with a very big sea running. When close to Mazzara engine trouble took place. It was only by the skill and nerve of the first pilot, Flying Officer Harris, that they got down safely. The conditions were a raging sea, a river with a breakwater across its mouth and a sideslip landing into a very narrow patch of calm water behind the bar; none too easy a job on an "F.2 A." with one engine.

They got into touch with us by W.T., using a kite for the aerial, and as soon as the weather moderated I sent over another "F.2 A." with two cylinders. The necessary replacements were made and both boats safely returned on the fifth day.

Squadron Leader Shepherd gave the "F.2 A.'s" names of planets, Venus, Mercury, Aquilla, etc. This was really a great advance and tended to smarten up the crews immensely. I have never seen better kept machines and they were all as efficient as it was possible to make them. They were not wet-nursed either. It must be borne in mind, besides these long flights we were carrying out constant naval and military co-operation work.

Flight No. 12.—On April 5th we set off to try to fly to Gibraltar. Fuel had been sent there and I had made arrangements also to fill up at Bizerta, Algiers and Oran. Five of us went, Scriven as first pilot, self as second, Gordon as observer, with an engineer and W.T. operator.

We got to Bizerta in average time, refuelled there, had our usual getting-off trouble and set sail for Algiers, intending to remain the night there.

We ran into a dead head wind with a heavy sea. After flying for four hours and making exactly 100 miles we decided it was essential to alight as we had only two hours' fuel left. We got down into Bona Harbour, all having had quite enough of it. We obtained petrol there and next morning attempted to get off. We found that we could not get off, the boat was leaking badly and as fast as we pumped it out it made it again trying to get off. We got rid of a lot of fuel and then decided to return to Malta as it was evident that I would not have time to get to Gibraltar and back and then fly up to Genoa to meet a distinguished personage. Our journey back to Malta via Bizerta was uneventful except for a strong wind. We did the 130 miles between Pantellaria and Malta in 65 minutes—not bad in a 70-knot machine.

Flight No. 13 was to Gibraltar. We set out on 16th of May, 1922, using a new boat—Scriven, Gordon, myself, the Constantinople flight engineer and a W.T. operator. Our earlier experience showed us that we could not expect a record beating flight as it was essential to keep our load as low as possible. We therefore went with 6½ hours' fuel—even this load is really too much. We started at daylight and had an uneventful trip to Bizerta, taking a little longer than usual. We refuelled there, doing it in a very short time and were ready to proceed in under the hour. We had our usual hard struggle to get off, wasting at least one hour, but at last we got into the air. We had quite a good flight to Algiers, arriving there about 4 p.m., alighted outside the breakwater, and taxied right up the harbour to the French Naval Base, where we found every arrangement made for us. We remained the night here according to plan. Next morning we got off in good style, as we found a nice choppy sea waiting for us. Oran was reached about 11 a.m. and after a slight delay we had our fuel. Unfortunately we found a big sea running in the afternoon and I reluctantly decided that it was inadvisable to try and get off. We therefore remained for the night. Next morning at an early hour we started for Gibraltar. There was a big sea running outside, but every minute was bringing us nearer our goal. We had some colossal bumps in the straits and when we got to the Rock; as a matter of fact we alighted with only about ten minutes' fuel left. It was sufficient, however, for us to taxy into the Cormorant Camber and moor up to a raft.

The mooring arrangements at Gibraltar were not good really, as the raft, although excellent for refuelling and carrying out some repairs to a wing tip float, was a bad business to lie at, being moored head and stern and not swinging. Gibraltar is a beastly place as the wind comes from all quarters simultaneously. We therefore secured the tail of the boat to the shore with a couple of grass lines. Next day we remained at Gibraltar.

On the following morning we nearly lost the boat as a squall carried away the stern lines and we narrowly escaped being wrecked. I did not like the weather very much as there was a strong easterly wind blowing, but it was essential to start on the return journey. The programme I mapped out was,

stop the night at Oran, then get on to Bizerta via Algiers on the next day. Unfortunately we never reached Oran. The afternoon was beastly, a head wind, big sea and low visibility. We soon realised that it would be touch and go if we got to Oran before either dark or our fuel ran out. I do not know a more wearing feeling than not to know whether your fuel will last out when you are flying over a big sea on which it is odds on you will crash on alighting. Just as I had calculated we could get there before our fuel ran out, but after dark, the reduction gear of our port engine went; we were at 300 feet and had to alight immediately. Scriven made the best rough sea alightment I have ever seen. We all shook hands once we were safely down. About two minutes before the reduction gear went I had sighted a sailing ship, the only ship we had seen for the last two hours. She was about two miles off. The situation was none too good. We were abou six miles off Cape Enegalo; sea very high, strong wind, lee shore all rocks, only one engine and less than 15 gallons of fuel left. This meant that we would not be able to keep her off the rocks. An "F.2 A." is a hard thing to keep head to wind with only one engine, but we managed to do it all right by using our drogues. After a bit we attracted the attention of the sailing ship, a vessel of about 250 tons—luckily she had an auxiliary engine. She came down to us, turned head to wind and sent a boat down to us on a line. After a bit of a job we got into tow and Gordon went aboard the ship to take control; gradually we got round tail to wind and headed for Beni Sof, a port about 15 miles off. After being towed for about an hour, all of a sudden the dinghy tore down on us and vanished amidst yells under the wings. One native was left clutching on to the drift wires. Trevelyan grabbed hold of him and dragged him on board, he remained all the night in the fins, blue with cold and fright. Gordon and another native were meanwhile adrift in the boat with only one oar. Of course the whole thing was a most absurd manœuvre as we were going along at about five knots. I thought this was the last I would see of Gordon; we kept on firing Verey lights and using the Aldis lamp as a searchlight. Luckily after an anxious half an hour I had the luck to get the Aldis light on to them. We drifted down on top of them and they regained the ship.

Beni Sof was reached without further bother early in the morning. We found that we had received damage to one lower plane. Taking everything into consideration the best thing appeared to be to ask for a destroyer with a towing lighter; replacing the engine is not an easy job without getting the boat ashore, as of course in an "F.2 A." you have to remove the planes. Later in the morning a French torpedo boat arrived. (I may here say that the French were as always most willing to help.) Mr. Barber, our Vice-Consul at Oran, and the French Naval Commandant had sat up all night expecting us; receiving no news they had sent out a torpedo boat and a submarine to look for us. In addition they had told Gibraltar we were obviously down. As the weather was bad Gibraltar sent out a destroyer. After a consultation over the telephone I decided that we would get the French torpedo boat to tow us to Oran. The day was calm and I anticipated little trouble once we could get round Fregalo. As a matter of fact it was a bad mistake. We set off merrily enough, but as soon as we got near our old spot it came on to blow like smoke. After struggling along and carrying away two lines I decided we must remove Scriven and Dunn, who were on board the Venus. We had a ticklish job doing this as the torpedo boat's dinghy could not possibly live in the sea. The only thing to do was to steer the torpedo boat for the wing tip and for the two of them to jump on board. It was splendidly carried out by the Frenchman after two abortive attempts. Unfortunately we severely damaged the wing. The only thing to do now was to let Venus drift. Personally, I thought she would soon sink as she was leaking very badly. We therefore hurried off to Beni Sof to get some more rope as we had expended all they had and had to wait for the wind to drop. Arriving there, Gordon and I climbed to a hill to look for Venus. About 5 p.m. I sighted her.

We set out once more, as the sea had dropped, secured her and brought her into Beni Sof; getting the leaks under we stuffed up a hole or two and remained for four days until the destroyer and towing lighter arrived from Malta. We got Venus on to the lighter in fine style and set off again; weather calm, everything smiling and fine. Sure as anything, when we got near Fregalo up sprang the wind and sea and I soon saw we were in for more trouble. We had to slow down as the captain was frightened of tearing out the bollards of both the lighter and the destroyer. The lighter was jumping and heaving very badly. To my horror I saw that Venus was getting adrift. We tried to turn round, not an easy job in the big sea; but after one colossal bound Venus fell off the lighter into the sea. (What had happened I afterwards discovered was that one of the securing slips on the lighter had carried clean away.) Venus rapidly filled and sank up to her upper plane. We stood by her some time and when only her tail was showing out of the water we set off for Oran. Venus, as a matter of fact, drifted ashore and we salved the engines and instruments. Thus the Gibraltar flight ended in disaster. This was the only "F.2 A." we lost on these flights and she was not lost when flying.

Flight No. 14.—This was made to Palermo and back, nothing of interest occurring.

Flights Nos. 15 *and* 16 were made to Tunis by two "F.2 A.'s" in company. Only interesting for the repairs done to one of the boats. The crew beached the boat and repaired two leaking seams, using greased cotton twine.

Flight No. 17 was carried out to Bizerta in order to assist at refuelling.

Flight No. 18 is of interest, as this was the longest flight made in one day. Carnegie and myself with one engineer and W.T. operator set off at 3.45 a.m. for San Raphael, near Marseilles, in France. I selected a route via Bizerta and Ajaccio as this gave us two refuelling stops and allowed us to go only carrying about six hours' fuel. Bizerta was reached without incident. The Aquilla was alighted, taxied to a buoy, moored up and had left the buoy again within 35 minutes after having embarked 200 gallons of petrol. This was pretty good work. We encountered the usual difficulty in getting off the water at Bizerta and we were at least half an hour at it. From Bizerta we had a quiet trip until we got to the north-east corner of Sardinia, where we had a rough time, especially flying through the Magdalena Channel. At Bizerta we alighted close to the French civil aviation station, moored up to a buoy, and then warped to the jetty where we lay nose on. Here we embarked 150 gallons of petrol and some oil. The petrol was pumped through a hose. We were off again in 1 hour 15 minutes—not bad work. Between Ajaccio and San Raphael we had bad visibility, but our navigation took us direct to our objective. Flying over the French seaplane base, we found a big swell running. Alighting, we damaged a wing tip float. After mooring up to a buoy and communicating to a motor boat, I decided it would be much more comfortable for us if we could get into the harbour. The French told us that the entrance was only about 120 feet wide and the small harbour was full of shipping. They said we would have to be towed in, but we much preferred to have a shot at it ourselves. Carnegie made an excellent job of it and we picked up a buoy in first rate style. The French were rather impressed by our manœuvres. The whole journey had taken us 16 hours, of which 13½ hours had been spent in the air. Distance we flew, 760 sea miles. To demonstrate we were not very tired, we changed, went ashore, dined and spent an enjoyable evening, coming back on board about 1.30 a.m.

We remained the whole of next day at San Raphael, and then steadily jogged back to Malta, stopping a day each at Ajaccio and Bizerta.

On our return the Aquilla was absolutely ready to do the journey all over again.

Flight No. 19.—Malta to Algiers. This flight was a most meritorious effort on the part of the late Flight-Lieutenant Curtiss. He attempted to fly to Gibraltar in one day on a Fairey 3D., carrying an engineer and W.T. operator. He had a lot of trouble, all due to bad floats, and finally his Fairey was too badly damaged at Algiers for the flight to be continued.

Flights Nos. 20, 21 *and* 22 were of little interest, except that it was a flight in company to Spax and back, undertaken by two "F.2 A.'s" and one Fairey. Each "F.2 A." carried a crew of five and the Fairey carried two. The Fairey had a bad time at Spax as the floats leaked very badly and we had to keep her beached on a mud flat.

Analysis of Results

Largest number of flights made by one officer, 8 Flying time, 123 hours 38 minutes.

Largest number of flights made by one man, 6.

Number of officers engaged on flights, 19.

Number of men engaged on flights, 15.

Total flights made, 21.

Total flying time, 238 hours.

Number of "F.2 A.'s" employed, 7, of which one did four flights.

Two Faireys were also used.

Casualties.—One "F.2 A." lost, one Fairey wing damaged, back axle and two after port undercarriage struts broken.

Refuelling Methods

On practically every occasion petrol was brought over to the "F.2 A.'s" in small boats, generally in 50-gallon drums or 12-gallon tins. It was soon found that the best method was to empty the petrol into 4-gallon tins in the boat and then put it into the tanks. The 50-gallon drums were impossible to handle on board an "F.2 A.," and the 12-gallon tins also being heavy and awkward to handle in addition, we used to waste a lot of petrol. Another advantage of decanting the fuel into 4-gallon tins was that we got it doubly strained, a fully necessary precaution, as some of the fuel we got was very dirty and had a lot of water in it.

We had a large petrol funnel which we could hang up by the aid of two slings to the upper plane, thus saving the use of a man who had to hold it up before some bright fellow designed the slings.

The tanks should have gauges that can be read from on deck. The "F.2 A." gauges were very bad and time after time one man would have to go below to see how the level stood.

The chamois leather had to be frequently removed from the funnel and cleaned. A ready attachment to the funnel in the shape of a band is required. The funnel itself should have a wind shield as otherwise so much petrol is wasted when refuelling in any wind. We had long lengths of rubber hose so that we could reach each tank. Towards the end we used a two-legged funnel so that two tanks could be filled at once. We often considered using a pump; but finally decided that however big the tank was the 4-gallon tin was the most reliable and least complicated. We always carried at least eight 4-gallon tins.

Whilst on the fuel question, I would like to add that it is most essential to have some rapid method of discharging petrol overboard out of the tank, whatever type your flying boat may be, as circumstances arise when you cannot get off with a heavy load.

Pumping Out Arrangements

Wooden hulls, however well built, will leak, especially so in hot climates. The same should not occur so frequently in the case of metal hulls, but it is certain that a certain amount will happen. It is very essential to have some reliable and quick method of dealing with water in the hull. The "F.2 A.'s" had a semi-rotary pump with leads into the various compartments. I soon found that it was practically useless owing to the leads getting choked up and the pump getting blocked. The pump was also awkward and tiring to manipulate; we tried many schemes but finally decided that a large garden syringe was the best, aided by a 4-gallon tin sawn in half. In the case of big boats a pump that could be either power or hand worked is very essential.

Lighting Arrangements

Whatever the size of the boat, electric light installation is required. Riding lights, internal illumination, inspection lamps, signalling lights are all required.

In the case of small boats a dynamo and accumulators will probably suffice; but in the case of large boats an auxiliary engine is, in my opinion, absolutely essential. This engine will be able to deal with:—

(1) W.T. whilst at rest.
(2) Electric lighting.
(3) Pumping.
(4) Cooking.
(5) Charging batteries.
(6) Anchor work.
(7) It might also deal with slow taxying.

Cooking Arrangements

It is absolutely essential that some method of cooking food both whilst in flight and at rest is provided.

Electric cooking is far and away the best method for reasons that are obvious.

If a good electric cooker is installed it would do all sorts of jobs besides preparing food, one of which is drying clothes. You frequently get wet through whilst living in a flying boat. If you have some method of drying your clothes you score tremendously; electric radiators are, I consider, a necessity not only for this, but for heating the sleeping quarters.

This may seem a great elaboration, but only those who have had to sleep in a boat after and before an eight hours flight know what a boon it would be.

Mooring Up Arrangements

Firstly, you should have efficient ground tackle. Your anchor or anchors should be capable of holding the boat on an average bottom. The anchor should be easy of stowage and as small in dimensions as possible. There is one slight difficulty that may have to be dealt with, that is, if you have one or two heavy anchors stowed forward you may upset the trim of the boat in the air, therefore your stowage place should be further aft. This could be easily arranged for. The cable should be preferably wire with the last two fathoms at the anchor end chain. The wire cable should be stowed on a reel and the reel should be either hand or power worked. Personally, I would carry two bower anchors of stockless type and one kedge anchor stowed aft. This is very useful for warping purposes. The cable of the kedge could be made of hemp. In addition to your anchor you require at least three mooring ropes, hemp for

preference, for (1) picking up buoys, (2) use as slip rope, (3) stern moorings when lying in a fairway and you do not want to swing, (4) mooring up to jetties, etc., (5) towing by motor boats.

If you moor up to a buoy your main anchor cables would be unshackled and used as mooring ropes.

In the extreme bows of the boat you should have a place where the crew can pick up a buoy or pick up a tow, work boathooks, etc. There should be plenty of room with the body exposed from the waist upwards and a solid foothold. Outside this there should be a walk where they stand, if required to jump off on to a buoy or jetty. In the cockpit or whatever you like to call it there should be at least one good bollard with a belaying pin and a good cleat on each side.

In a rack or clips should be stowed a picking-up hook consisting of a light boathook fitted with a spring hook to which is attached a light line—this line should be run through a fairlead on the hook so that a heavier line could be hauled out to the buoy. The boathook need only be about 12 feet long and it might be made collapsible for easy stowage. Whilst on this subject I would say always have the inboard end of any line made fast. How often have I seen boats adrift because the crew have omitted this.

However big the boat it should be able to pick up its own buoy or to go to jetty under its own power, whether main or auxiliary power plant.

However experienced the crew there are occasions on which you bump your objective, therefore a fender is essential. After a little experience we always carried one and it saved us many a stove-in plank. I can by now see that many of the audience are thinking how the devil will a boat get into the air with all this junk. We used to and with old soggy boats of antique design—and you cannot do without it. If each article is properly designed you will find that you can still fly. I would lay down that in the design of any flying boat they should fix the position of all these essentials and allow for them, just the same as in a single-seater fighter you fix the gun positions, although there have been instances I have encountered recently where guns are fixed firing directly into the engine. I don't know personally whether this is being done at present, but hope that it is. In every design of flying boats somebody with real practical experience of their manipulation whilst on a cruise should be consulted—otherwise you get a regular Christmas tree and end up by carrying twice the weight in extras that you would have done if they had been properly designed. I would most strongly impress upon you that the flying boat will never fly more than once or twice unless its existence on the water is as carefully considered as its existence in the air.

The use of drogues is required on all occasions of picking up moorings, manœuvring in restricted spaces, warming up engines, riding out at sea, etc., etc.

The drogues should be capable of being spilt and opened by the manipulator at will. They are worked from each quarter and a cleat should be fixed for the lines in a handy position.

If you have to lie at moorings during strong winds, you should be able to weight your boat down with water by taking in water ballast in the hull. This will prevent you flying at your moorings. If you have wing tip floats I would like them made so that you could weight them down with water ballast.

Internal Design of the Boat

First and foremost, there should be a good passage way all along the hull. The interior should be light and well ventilated. The pilot if he turns round should be able to see the members of his crew.

W.T. compartment should be directly behind the 1st pilot.

All the crew should be able to look out, apertures being made in the hull close to their stations. The hull should be made so that the crew can walk along outside or over the top.

Every cockpit or aperture should have a cover to it, especially so the front cockpit, which should have a sliding watertight cover. The pilot's wind screen should have an electric wiper.

The petrol tanks should be so constructed that they can be placed at the sides of the hull or under the deck.

Engines should be so mounted that they can be removed by the crew without dismounting the planes. The engines should be accessible to the engineer during flight. Exposed lengths of petrol and oil piping are a nuisance as well as being a source of trouble.

The propellers should be so placed that they are out of the way of the water thrown up by the hull, also well clear of the water. This may be difficult to accomplish.

The step or steps should, if possible, be adjustable. This may be impossible; but it would be invaluable on occasions.

The design that appeals to me is one that permits of the engine being in the hull itself under cover, with propellers driven by shafts through gearing.

A gravity feed to the carburettors is also desirable with main tanks, either in the hull or if not desirable to do this, placed in the wings.

If possible, do away with wing tip floats; they are always a source of trouble and danger.

A pathway along the planes is essential, also one overall to the tail.

Good watertight sub-division of the hull is necessary, the bulkheads being carried above the waterline.

Cupboards should be provided for :—

(1) Tools.
(2) Accumulators.
(3) Cooking and eating utensils.
(4) Clothing.
(5) Stores.
(6) Spare parts.
(7) Charts, instruments, navigational books, etc.

This can easily be done without much additional weight, and certainly in some cases at a great saving of weight. A light cupboard for your clothes for instance is much lighter than using a suitcase, also clothes can be kept dry. These cupboards also obviate gear sculling about all over the place.

Sleeping Accommodation

Light bunks as we made in the Mediterranean were a godsend. They only weighed about 12 lbs., and were hinged up against the sides of the boat when not in use. Each bunk had a sleeping bag attached, this bag being made of aeroplane fabric. Aquilla's tail was a sight for foreigners to be shown. We had two bunks, electric light, electric fan, and photographs stuck up on the sides. It made good propaganda. It was quite comfortable except for Carnegie's snoring.

Discussion

Mr. W. O. Manning, in opening the discussion, said that he was sure that all of those who were interested in the design and construction of flying boats were very much indebted to the lecturer for the information he had given them. The labour that the lecturer had spent on his paper ought to result in better boats being built.

One point on which he would like information was regarding the weight of anchors to be used in flying boats; what weight of anchor was necessary to hold an F.2A.?

Another point on which he was not quite clear was as to what the lecturer meant by the term "adjustable steps."

With regard to having the engines in the hull, he thought this might lead to complications and considerably more weight.

He would like to know whether the lecturer had had much trouble with maintaining the various etceteras in the boats, such as greasing wires and so on. Had he found that drogues broke or burst?

In modern types of boats the petrol was carried outside the hull on the planes, leaving most of the hull clear, which certainly seemed an advantage, but he thought that it might be difficult to send a man up ten or fifteen feet above the boat when refilling the tanks.

He thought that the detail mentioned by the lecturer of the importance of having a gauge that could be read from the deck was one that should be considered. The paper had been one of immense interest.

Captain Nicolson said that the audience were very much indebted to the lecturer for giving them the benefit of his experiences with the F.2A. flying boats, even although they were now out of date.

He certainly agreed with him that it was most important to have the hull of a flying boat as seaworthy as a motor boat. He (Captain Nicolson) had pointed out for many years that any hull built on the constructional methods employed on the F.2A. boats could not be seaworthy, and was glad to note that the lecturer had proved this. Although these facts are known to practical men, yet many designers of to-day ignore same as they design a flying boat, assuming she will be in the air nearly all her life. The real truth is that most present flying boats spend really all their time on trollies, which again should not be. A seaworthy hull that could fly was what was required, and could be accomplished if the best yacht builders had a free hand.

He did not agree with the lecturer when he stated that wooden hulls must leak. One hydroplane designed by him in 1909 still did 30 miles per hour, and has been in use every season since, with the exception of the five years during the war. This boat might leak a little at the beginning of the season, but once she has taken up lets no more water in all the season.

Hydroplanes perform similar functions to flying boat hulls, and have in many cases to stand up to greater hammer blows from waves and have to remain on the water for much longer periods, and nearly all these craft prove to be seaworthy.

Before passing he should like to quote another example. Messrs. Saunders, of Cowes, built "Maple Leaf IV." in 1912, and that year she brought back to this country the International Cup, and in the following year she defended same in this country. During the years 1914 to 1918 this boat was thrown outside to make room for war products, and in 1920 was again put into commission and is still running, doing higher speeds than flying boats are asked to do on the water, and yet she does not let half a gallon of water in per month. Many more examples could be given to prove that wooden hulls do not leak; it was simply a question of design, but it took a competent naval architect to design it.

It will be very many years before the metal hull will supersede wooden hulls, unless we come to boats of much larger dimensions. This has been proved by many of the leading shipbuilding firms, as they tried some time ago to use metal lifeboats, but most of these have been scrapped, and they have after a great many trials come back to the wooden hull.

In his opinion, when large flying boats are required, the composite hull should be the preceding step to metal boats. This would then be following the practice of the ship and yacht builders of this country, which have made them renowned throughout the world.

The Air Commodore had asked if the steps could be made adjustable and Mr. Manning inquired what exactly he meant by this. He (Captain Nicolson) understood that he meant adjustable forward, aft, or over the centre of gravity. That could easily be done, and had been tried not only on models, but with a small boat, and he held at present plans for adapting this to flying boats.

With reference to Air Commodore Samson's remarks that it would be a great advance if a boat could be built so that the spray would be kept clear of the propellers. This again was only a question of design, and Messrs. Saunders have a boat at Felixstowe which has demonstrated that the water can be kept clear of the cockpits and propellers, and also give easy landing.

He again thanked the lecturer for having brought such an important matter before the Society.

Flight Lieutenant D. V. CARNEGIE, A.F.C., said that the cause of the engine failure mentioned by the lecturer as having taken place while they were between Corfu and Santa Maria di Leuca, was evenutally found to be due to a slight crack in the carburettor water jacket, which let water through into the petrol.

He thought that there was a fine field for commercial aviation from the flying boat point of view in the Mediterranean. The only line working appeared to be the one between Ajaccio and the French coast. The conditions were extremely fine compared with those in the British Isles, as fog, for example, was practically unknown and gales were of rare occurrence and of short duration.

Up at Invergordon, where they had been sent on a fishery cruise looking for herrings which, incidentally, they never found, although their boat, which had been built at Gosport in 1918, had been moored out for six weeks and was thoroughly sodden, yet they got off with 350 gallons of petrol, which enabled a flight of nine hours to be made. A good deal of the trouble they had had in the Mediterranean in getting off was due to the lesser density of the air.

Several of the improvements suggested by the lecturer had already been adopted in more modern machines. Unfortunately the lecturer had gone over to land machines since these had been incorporated. In some of the modern machines, for example, it was possible to take the engines out without having to take off the wings, propellers were being kept more clear of spray and petrol tanks were stowed away carefully inside where they were not in the way.

He wished to emphasise the point that the flying boat's existence on the water was equally important to its existence in the air, and was of opinion that not enough was made of this water side of the matter, while performance in the air was considered to be everything. He thought that some modern types would be quite useless in a rough sea, such as even the despised F.2A. would be able to stand with ease.

Mr. M. H. VOLK gave an account of a month's experiences in 1919 with Colonel Hope-Vere and Flight Lieutenant Carnegie in an F.5, when they flew from Southampton to the Zuyder Zee (Amsterdam) and travelled through Belgium back to Felixstowe. Nearly all their troubles were on the water with mooring and handling.

The final trip from the Zuyder Zee (Amsterdam) to Felixstowe was eventful. There was a 60-mile wind blowing and they had to alight in Harwich Harbour in quite a rough sea and it was about 2¼ hours before a R.A.F. picket boat could get to them. All that time they were taxying into the wind to prevent the boat drifting ashore. Practically no damage was done and no repairs were necessary throughout the whole month's tour. He wished to emphasise the point that nearly all the difficulties with flying boats were on the water and not in the air, although on that particular trip the hull did not leak. On one occasion they took off across a canal in the middle of Amsterdam without difficulty. The Gosport boat referred to by Flight Lieutenant Carnegie was also an F.5.

Wing Commander T. R. CAVE-BROWNE-CAVE agreed that an auxiliary engine would have many uses in a large flying boat. The provision of such an engine for the N.4 type had been considered and one of the advantages claimed was that it would be available for warming and starting the main engines, which in that seaplane were somewhat large to start by hand under difficult conditions.

He inquired what precautions against fire were taken during the cooking and similar operations described in the lecture. The presence of petrol tanks inside the hull was a constant source of danger of fire. Tanks under the wings had many other advantages besides that of safety from fire and he should like the lecturer's opinion about them.

It seemed difficult to discover exactly what forces had caused these boats to leave the water with such loads. There must have been a good deal of moral force in addition to those forces which usually appear in the equation. The whole lecture reminded him of a saying of Napoleon—one which was often quoted in the Staff Colleges, but seldom before the Society—" The moral is to the material as three is to one."

Flight Lieutenant B. C. H. CROSS, R.A.F., said that he was sure they were all very grateful to the lecturer for his excellent paper. One realised that the pioneer flights he had described were the beginning of a new era, when flying boats were going to be entirely self-dependent. Squadron Leader Maycock, in his paper before the Society last year, had described his experience in home waters on similar lines, and the two papers considered together were a very thorough indication of the value of flying boats under varying conditions.

This work was being carried on by the service and he was of the opinion that progress was being made. During the last summer three flying boats were maintained in the north of Scotland for five weeks on the water, in the worst possible weather and without cover of any kind. At the end of this period two machines returned to base via the West Coast while the third made a direct flight in nine hours. This was a distinct advance and represented the results of experience in reducing considerably the factor of deterioration with its effect on performance.

An engine had for the first time been changed on the water. An F.5 had been compelled to put in to Folkestone with a damaged engine; it was warped under a crane and the old engine hoisted out and a new one fitted.

Little progress had been made with the design of a pump to bilge the boat and similar pumps to those described in the paper were still in use. The anchor question was still unsolved.

Lieutenant-Colonel H. T. TIZARD, before asking the lecturer to reply to the discussion, said that there was no doubt of the importance of the long distance flights he had described. One was very sorry to see that the opportunities for these pioneer flights seemed to get less and less each year. He hoped that when the financial position of the country allowed the funds would be forthcoming for these large-scale experiments to be continued, as they were absolutely essential if they were to make a practical success of flight.

The lecturer's naval training showed in every line of his paper; in his resourcefulness, in the accuracy of his records and the practical way in which everything was done. Designers might consider some of the things the lecturer had asked for unnecessary, but without them the experience of the lecturer seemed to show that flying boats were commercially impracticable.

From his own experience he thought that an auxiliary engine could be made that would be useful for the purposes for which the lecturer had shown it was required.

The paper was a most valuable record of one of the most interesting and strenuous series of flights that had ever been made.

Air Commodore C. R. SAMSON, in replying to the discussion, said that the weight of an anchor for a F.2A. ought to be about 50 lbs. That was roughly the limit of what could be carried, and two would be necessary.

Captain Nicolson had answered the question regarding an adjustable step.

With regard to having the engines in the hull, he was an amateur in these things and did not quite understand why the gearing would be complicated. The advantage of having them in the hull would outweigh the complication in his opinion. There had been several machines flown with gear-driven propellers, also chain-driven.

He had had no trouble at all with drogues and none had been reported to him.

If the petrol tanks were on the upper planes a man could climb up and tins could be passed up. Of course, pumping the petrol up would be best; it would be fairly easy that way. When taking in petrol, if one had a re-fuelling tank on deck from which tank pipes were led to each of the main tanks, all you had to do was to pour the petrol into the refuelling tank and open each cock as it was required. It saved a lot of trouble. The refuelling tank could be of only about two-gallon capacity.

It was most important that the petrol gauge should be where it could be read from the deck, also by the pilot whilst in the air. If the engineer were asked he always under-estimated the amount left in the tanks.

He was glad to hear that there were wooden hulls that did not leak. Every one he came across leaked, especially so in hot climates. He was pleased to know that propellers in modern machines were out of the spray thrown up by the hull.

He was interested in Flight Lieutenant Carnegie's explanation of the engine failure at Sta. Maria di Lucia. Few people realised how much Carnegie had done with flying boats. At Malta he found a machine which had been tested by him in 1917. He had done more flying in flying boats than anyone else.

It was surprising that more flying was not done in the Mediterranean. Why did not someone run a line from Marseilles to Suez, so that people in a hurry could go by air instead of in a steamer? It could easily be done if they had boats like the "Felixstowe Fury," and carried on developing from the type in 1919.

A hand-rail was not wanted for the walk-way in a flying boat. The man who needed one would be no good to them.

He was glad Wing Commander Cave-Browne-Cave agreed with him that an auxiliary engine was worth having. He had never had any trouble with engine starting; the work was rather a good thing on a cold day.

With regard to the precautions they took against dangers of fire, they put the Primus stove in half a petrol tin which they put on the tail and they never had any fire.

Petrol tanks in the hull were presumably dangerous, but they had no fires. They always had too much loose petrol in the hull, due to bad refuelling arrangements. There was plenty of room in the hull for the tanks, and it kept the weight well down instead of up. In any water manœuvres the less weight above the better.

It seemed a pity to use flying boats for hunting herrings. It would be better to let them fly out to Malta, etc., they would learn much more.

He did not think it was feasible to change an engine in the water in the cases in which the planes had to be removed. One did not find cranes everywhere.

With regard to the accurate record keeping, remarked upon by the Chairman, he had had a very hard-working staff who did it all.

RELIABILITY OF AIRCRAFT ENGINES

BY J. D. SIDDELEY, C.B.E., F.R.AE.S.

The progress of mechanical flight to the present stable position occupied by aircraft as a means of transport has been so closely related with the problems associated with the development of the power unit, that an examination of such an important factor as its "reliability" appears justified.

In searching for possible means to produce power, it was natural that the use of steam as a motive power should have been considered. First Langley and then Maxim in 1895 produced a steam plant designed for aircraft. No practical success was attained by these early efforts, and a considerable period elapsed before the successful power unit for aircraft was evolved.

Even to-day, the use of steam to obtain increased reliability is advocated as a prime mover, but it must be borne in mind that the high degree of reliability attained in steam practice, has been, within limits, unrestricted by weight considerations.

The weight power ratio of standard types of modern steam engines alone are as high as, and will vary as much as, from 150 lbs. to 300 lbs. per B.H.P., and whilst the modern condensing steam turbine has resulted in a considerable advance an analysis of the problem will demonstrate the practical limitations to the use of steam in aircraft.

From a detailed investigation, it will be found possible to produce a complete power plant designed specially for aircraft for a power output of 1,500 B.H.P. with a weight of 4.0 lbs. per B.H.P. output.

Such a plant, however, involves :—

(*a*) Steam raising unit, generating steam at high pressure.

(*b*) High speed turbine unit, embodying a reduction gear to obtain a suitable propeller speed.

(*c*) Condensing unit.

In addition, the plant will necessarily comprise auxiliaries, such as means for inducing draught (if only for starting purposes), fuel pumps, condensate pump, feed pump, etc.

It will be found that the power plant so represented, becomes not only a delicate, but a bulky and unwieldy apparatus.

From aerodynamic considerations the resistance of the condensing unit becomes a serious factor, and as will be shown at a later stage, the introduction of a system with water, or any other suitable medium, forming a necessary part, introduces a feature which considerably influences the degree of reliability of the power plant as a whole.

The thermal efficiency of such a plant would not be higher than 16 per cent. to 17 per cent., and although the employment of a fuel cheaper, and safer than that now in general use is attained, the effect of the lower thermal efficiency of the plant on the load-carrying capacity of the aircraft becomes an important consideration.

The limitations are therefore so serious as to render the use of steam in the light of present knowledge impracticable.

The flight of the Wright Bros. in 1903 clearly demonstrated the possibilities of the internal combustion engine in producing motive power for aircraft, and the subsequent successful flight in France, using the Antoinette Engine and the

Anzani Engine, one of which was used by Bleriot in his first Channel flight in 1909, were milestones in the history of the successful development of the heavier-than-air power plant unit.

The first great advance, however, was made by the production of the Gnome rotary type of internal combustion engine, and its influence on aircraft developments cannot be over-estimated. This principle was employed, as represented by successive types, during subsequent years, and was only superseded when the demand for higher power outputs arose.

The type possesses important defects, for example :—

(*a*) Due to windage losses the mechanical efficiency is 10 per cent. to 12 per cent. lower than the corresponding static type.

(*b*) Restrictions are imposed on valve details due to high centrifugal loads.

(*c*) Cylinder cooling is inefficient.

The only advantages possessed by the type are :—

(1) Crank balance weights are not required.

(2) The stresses on the big end bearings are relatively lower.

(3) The problem of mixture distribution is simplified, although this is attendant with certain disadvantages due to the principle involved.

Whilst more efficient cylinders could be designed and improvements generally introduced, the inherent weaknesses are of such a serious nature as to render its comparison with the static type unfavourable.

Developments were therefore confined to the static type of internal combustion engine, and the types still in general use employ either air or water cooling, functioning on the well-known constant volume cycle.

The most important original developments since 1914 have been conducted in this country and the possibilities of practically every mechanical type have been explored.

These types are represented diagrammatically in Table I.

All these types have their representative advantages, but from a review of their characteristics as a result of the intensive developments carried out, it would appear that their number could be reduced to two or at the most three types.

It is suggested that this result could be achieved without in any way sacrificing aerodynamic efficiency at least until the conception of an entirely new type of power unit demands a reconsideration of the whole problem.

The phases in the transitory stage of development of the Internal Combustion Engine for Aircraft since 1910 are shown in Table II., which denotes also the important basic characteristics of various well-known types.

If these interesting details are examined it will be observed that within this period of development—

(*a*) The brake mean effective pressure has been increased by 75 per cent.

(*b*) Piston speed has increased up to 100 per cent.

(*c*) Brake thermal efficiency has been increased by 33 per cent.

(*d*) The weight per B.H.P. has been decreased by 170 per cent.

The importance of these developments is not fully represented by the above comparison unless it is also recorded that the standard of reliability has been at least doubled, accepting the British Air Ministry official type test as a measure of this standard.

Another important aspect closely related to the standard of reliability is the period elapsing between complete overhauls. From accurate data compiled over lengthy periods of observation this period has been increased by 350 per cent.

TABLE I.

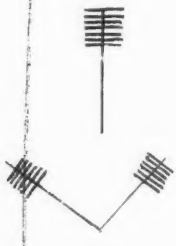
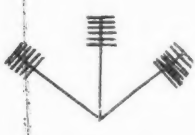
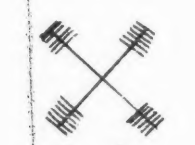
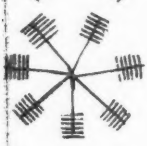
Type.		Air-cooled and water-cooled.
Vertical.		4, 6 or 8 cylinders.
Two row "V."		8 cyl. 90° or 12 cyl. 50 or 60°.
Three row arrow.		12 cylinders.
Cross.		16 cylinders.
Radial.		3, 5, 6, 9, 14 and 18 cylinders.

TABLE II.

AERO ENGINES BEFORE 1910.

Name of engine ...	Wright.	Green.	Anzani.	Wolseley.	Renault.	Gnome.
Type of engine ...	Vert.	Vert.	Fan.	Vee.	Vert.	Rotary.
Cooling System ...	Water	Water	Air	Water	Water	Air
Number of cylinders	4	4	3	8	4	7
Bore of cyls. ins. ...	4·25	5·52	3·94	3·74	4·33	4·35
Stroke of piston ins.	4·33	5·75	5·92	5·0	6.30	4·73
Brake horse-power	24	60	25	54	38·5	45
Brake M.E.P. lbs. sq. ins.	64.48	78.5	65.33	88.47	74·71	65.85
Revs. per minute ...	1200	1100	1400	1350	1100	1100
Piston speed ft. per min.	870	1015	1380	1125	1155	870
Dry weight of engine lbs.	210	236	140	300	286	172
Weight per B.H.P in lbs.	9.2	4·44	5.6	6.1	7·9	3.8

NOTE.—0.5 lbs. added to weight per B.H.P. on water cooled engines to allow for cooling water.

TABLE II.—*continued.*

PARTICULARS OF LEADING ENGINES IN 1914. TEST FIGURES.

Name of Engine.	Argyll.	British Anzani.	Dudbridge Salmson Cantonunne.	Beardmore Austro-Daimler.	British Gnome Mono-Soupape.	Sunbeam.	Green.	Wolseley. F.2.	Wolseley. Renlt.
Type of engine	Vert.	Radl.	Radl.	Vert.	Roty.	Vee	Vert.	Vee.	Vee.
Cooling system	Water	Air	Water	Water	Air	Water	Water	Water	Water
No. of cylinders	6	10	9	6	9	8	6	8	12
Bore of cyls. ins.	4.92	4.53	4.72	5.12	4.33	3.51	5.51	5.0	3.78
Stroke of pistons ins. ...	6.89	6.10	5.51	5.89	5.9	5.9	5.98	7.0	5.51
Brake horse-power	116.6	100.2	124	129	99.2	130.9	103.5	139.6	113.5
Brake M.E.P. lbs. sq. ins. ...	48.95	36.39	44.25	47.12	42.71	54.37	38.52	39.44	33.64
Revs. per minute	1200	1100	1276	1275	1206	2046	1242	1238	1800
Piston speed ft. per min. ...	1378	1129	1172	1464	1187	2014	1239	1445	1654
Fuel per B.H.P. hour lbs. ...	0.57	0.95	0.55	0.54	0.69	0.53	0.63	0.58	0.66
Weight of engine complete with cooling system ...	600	464	545.6	538.8	275	565.1	507.3	810.7	478.8
Weight per B.H.P.	5.15	4.64	4.4	4.52	2.77	4.32	4.9	5.81	4.22

TABLE II.—*continued.*

ENGINES OF 1924.

Name of Engine.	Napier Lion.	Rolls Royce Condor.	Jaguar.
Type of engine	3 row arrow	Vee	Radial
Cooling system	Water	Water	Air
No. of cylinders	12	12	14
Bore of cylinders, ins.	5·5	$5\frac{1}{2}$	5
Stroke of piston, ins.	5·125	$7\frac{1}{2}$	$5\frac{1}{2}$
Brake horse-power	470	670	405
Brake M.E.P. lbs. sq. ins. ...	127	127	125
Revs. per minute	2000	1900	1700
Piston speed, ft. per min. ...	1710	2215	1560
Fuel per B.H.P. hour lbs. ...	.49	.49	.500
Dry weight of engine	930	1320	780
Weight per B.H.P.	2.48	2.47	1.93

NOTE.—0.5 lbs. added to weight per B.H.P. on water cooled engines to allow for cooling water.

TABLE III.

Group.	1922 TYPE. Weight per B.H.P. lbs.	1922 TYPE. % of Total Weight.	1924 TYPE. Weight per B.H.P. lbs.	1924 TYPE. % of Total Weight.
Cylinders	0.742	31.7	0.5675	28.1
Pistons and conn. rods ...	0.238	10.2	0.224	11.1
Valve gear	0.266	11.39	0.2562	12.7
Crankshaft	0.216	9.22	0.196	9.7
Crankcase	0.34	14.57	0.293	14.5
Induction	0.1718	7.34	0.148	7.35
Lubrication	0.021	0.9	0.0182	0.9
Ignition	0.186	7.95	0.17	8.4
Air screw hub	0.057	2.43	.052	2.56
Miscellaneous	0.1004	4.3	.0946	4.69
Total ...	2.3382	100.0	2.0195	100.0

From authoritative sources proposals have been consistently put forward that the standard of reliability of the aircraft power unit should be improved by providing a more robust unit, increasing the weight/B.H.P. ratio.

Such proposals should, however, be the subject of careful consideration.

The progress of aviation is linked in the closest degree with the performance of the power unit, the whole design of the aircraft being influenced not only by the type, but the performance, as represented by the weight/B.H.P. ratio, and the thermal efficiency, which exerts an important effect, especially in long range aircraft.

It must be admitted from the information at our disposal that the development of the power unit has been consistently maintained, and that the factors which influence the progress of aviation have been appreciably improved.

An actual example, where the reliability factor has been doubled, based on official statistics is given in Table III. The weights of the component parts are expressed as a percentage of the total weight, and also in terms of weight/B.H.P., the developments representing a period of two and a half years.

It may be suggested that these details convey little information of value, and bear no relationship to the question of reliability. Without explanation this is true, but a study of the sequence of developments will indicate in what manner these improvements have been obtained.

It is proposed to refer to two important problems and to consider each component separately, and examine the factors which not only have limited the degree of reliability, but also the performance.

(1) It is perhaps not fully appreciated that a considerable amount of mechanical unreliability can be directly attributed to the use of unsuitable compression ratios. It should therefore be a basic principle that a compression ratio should be determined, depending on the cylinder design, suitable for the grade of fuel in general use.

Pre-ignition, detonation, consequent overheating with the resultant stresses imposed on mechanical details from this cause, have been a very prevalent source of trouble and unreliability, and can be obviated by a preliminary investigation of the characteristics and application of the power unit.

(2) The water circulating system of the water-cooled type has not only resulted in mechanical, but very frequently functional troubles.

In the water-cooled type of engine the water circulating system, based on statistics compiled over a considerable period, is responsible, apart from forced landings, for 45 per cent. of the total cost of maintenance.

The correct functioning of the water circulating system has also been a fruitful source of trouble. There are always occasions on which the water may boil, and it is important that freedom in the system is provided. Restrictions by small pipes, short bends in the water circuit must be avoided, and proper allowance made in the system to allow steam to separate from the water. The possibilities of water leaks developing if steam is trapped in the water jackets will be readily appreciated.

The use of welded joints and connections has been contributory to the cause of trouble, and even when extreme care has been exercised and the workmanship good, immunity from trouble cannot be assured.

Failure has further arisen from :—

The stress imposed in fitting induction and exhaust manifolds to mal-aligned cylinders.

Vibration due to :—

(*a*) Airscrew out-of-balance.

(*b*) Running at speeds at which periodic vibration is set up.

(*c*) Cases where the engine installation or mounting is defective.

(*d*) Certain running conditions, such as running throttled down with advanced ignition.

It must be borne in mind that an emergency may arise, when not only expansion of production will be required, but a lowering of the standard of personal responsibility for the handling of the units in service would result. It is important, therefore, to minimise the troubles arising from the water-cooling system, that "welding" should be entirely deleted. A satisfactory welding repair cannot be made by locally welding the leakage. It is essential that the welding round the leak should be brought to almost the welding point, so that the blending with the new welding is obtained. The best appliances and expert labour are a necessity to ensure a satisfactory repair.

Careful consideration must also be given to the source of water supply. Examples of cylinders and jackets corroded or pitted to necessitate scrapping have arisen after comparative short periods of service.

(*a*) *Cylinders, Valve, Valve Mechanism*

The defects and limitations of this component have been generally due to defects in design and improper distribution of mass.

Very considerable improvements have been effected by a better distribution of mass resulting in lower and more uniform cylinder temperatures, with the avoidance of "hot spots."

This has been particularly noticeable in the cylinder head design, where better provision has been made for cooling and conducting the heat from the valve seats and valve guides.

Not only have these improvements increased the degree of reliability, but they have enabled the power output and thermal efficiency of the unit to be increased.

(*b*) *Valves*

Warping of the valves and breaking and stretching of the stems has been reduced by the improvements introduced in cylinder head designs for dissipating the heat, and the use of improved material, the physical properties of which are better adapted for the duty.

(*c*) *Valve Mechanism*

The problems associated with these details have largely arisen from an incorrect provision for the stresses imposed, together with the difficulties due to synchronous periods peculiar to the valve springs. Material problems have at stages been evident, and attained serious proportions in valve springs principally due to laps or seaminess in the wire.

(*d*) *Pistons, Piston Rings and Gudgeon Pins*

The early difficulties experienced with aluminium pistons have been overcome. Burning and stress failures have been avoided by a more extended knowledge of the problem, resulting in the adoption of better designs to obtain a gradual temperature gradient, and the dissipation of the heat.

Piston ring and gudgeon pin troubles have usually been secondary and with the removal of the primary cause have been immune from trouble.

(e) *Connecting Rods*

Apart from isolated failures due to defects in design and material, the limitation to life and resultant reliability has been due to failure of the white metal or anti-friction metal employed in the big end bearing.

This is attributed to two causes :—

(*a*) Defective adhesion of the bearing metal.

(*b*) Local flexure of the shell of the big end bearing.

Both these problems have been the subject of investigation and considerable experimental work, and the life and reliability have been appreciably increased.

(f) *Crankshaft*

Again neglecting for the moment the failure due to material, this component has been immune from trouble.

Whilst the material troubles have been lessened as the result of improvement in manufacture, the long, multi-throw crankshaft is a problem of extreme difficulty due to the necessity of obtaining that uniformity of structure which the factor of safety demands.

(g) *Crankcases*

This component has been a frequent source of trouble, and the subject of review at more stages of development than possibly any other component.

It is suggested that this is due to the impossibility of laying down a factor of safety within sufficiently narrow limits to provide for the variations which occur in the aluminium alloy casting.

Considerable improvements have taken place :—

(1) By the designers' attempt to make the founders' task more easy.

(2) Treatment to relieve casting stresses.

The extensive employment of large and difficult castings, in any type of aircraft engine, is one beset by many dangers, and particularly when an emergency arises to necessitate production taking place on a large scale.

(h) *Reduction Gears*

The inclusion of this component in the design has been responsible for limiting seriously the degree of reliability of the power unit. Considerable progress has been made, but the difficulties have by no means been solved.

A stage existed when this component controlled the period between inspection and overhauls on the power unit. Improvements in the methods of manufacture, particularly as affecting the tooth form, have been responsible for a very considerable increase in the degree of reliability, but to-day it is suggested that it represents one of the chief factors controlling the standard of reliability of the power unit as a whole.

(i) *Auxiliaries*

Water Pumps and Connections.—There are troubles which are inseparable from these details. Foreign matter in the system such as sand, which in certain countries it is impossible to obviate, loose solder from radiators, deposit from unsuitable water, lodge in the circulation system and pump. Wear of pump bearings, restriction of the circulation, with consequent overheating has resulted, apart from possibilities of corrosion.

Due to the usual gradual effect, and warning given, failures have been obviated.

Oil Pumps and pressure control valve have been practically immune from failures. Any trouble usually is associated with air leaks due to defective assembly or foreign matter in the pump or connections.

Ignition System.—The extensive employment of wireless communication and reception equipment has imposed a severe duty on the ignition system, and even with this increased duty, the degree of reliability has been improved. Of the failures which have arisen it is interesting to record that they are chiefly due to mechanical defects.

Conclusion

It is considered that the improvement which has been obtained in the degree of reliability of the power unit is due to :—

(*a*) A clearer conception of the problems involved, which have been advantageously reflected in the design.

(*b*) The use of materials with higher physical values, more uniform in structure.

(*c*) Improvements in manufacture, a factor equal in importance and effect to (*a*) and (*b*).

Whilst still keeping to conventional lines of design, along which channel or channels does future progress lie?

It is suggested that no deviation is necessary from the path which has been followed, and progress will result rather from a broadening of these channels.

There are still many avenues associated with the details of the aircraft power unit which have not been fully explored.

It would appear, however, that the most reliable form of power unit, from a review of the information at our disposal, will be one in which—

(*a*) The design allows of bulky and stressed castings to be deleted and substituted by forgings or pressings.

(*b*) Forgings can be employed which are small relative to the duty performed.

(*c*) Water or indirect cooling is eliminated.

THE REACTION OF A STREAM OF VISCOUS FLUID ON A ROTATING CYLINDER.*

BY MAJOR A. R. LOW.

(*Continued.*)

Prandtl's Explanation.

In "Die Naturwissenschaften," 6th February, 1925, p. 93, there appears an article by Prandtl entitled "'Magnuseffekt und Windkraftschiff," giving the following explanation of the phenomena under consideration.

In a stream of viscous fluid a non-rotating cylinder builds up an accumulation of retarded fluid with considerable vorticity (Fig. 5). This fluid reaches

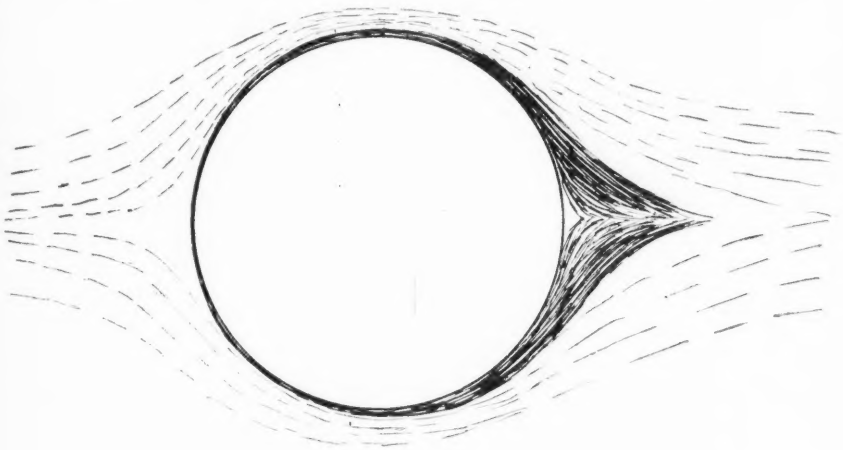


FIG. 5.

the neighbourhood of the near dead water point with a loss of kinetic energy and velocity by dissipation. At the somewhat indeterminate boundary of the boundary layer it is in contact with fluid which has lost its kinetic energy and velocity in acquiring an increase of pressure approaching the dead water pressure. The retarded fluid is pushed away from the dead water point by the higher pressure fluid (Figs. 6, 7), and ultimately it breaks up into cylindrical masses which are detached and carried away by the stream (Fig. 8).

When rotation is imparted to the cylinder, the viscous retardation is (initially) greater on the lower side where the surface velocity is opposite to that of the general stream, and low on the upper side where the velocities are in the same direction. Thus larger rotating cylindrical masses are detached on the lower than on the upper side, and the corresponding counter circulation round the cylinder is in the sense required to produce lift (Fig. 9).

* Erratum p. 104, line 11, for " non-rotating cylinder," read " cylinder without end caps."

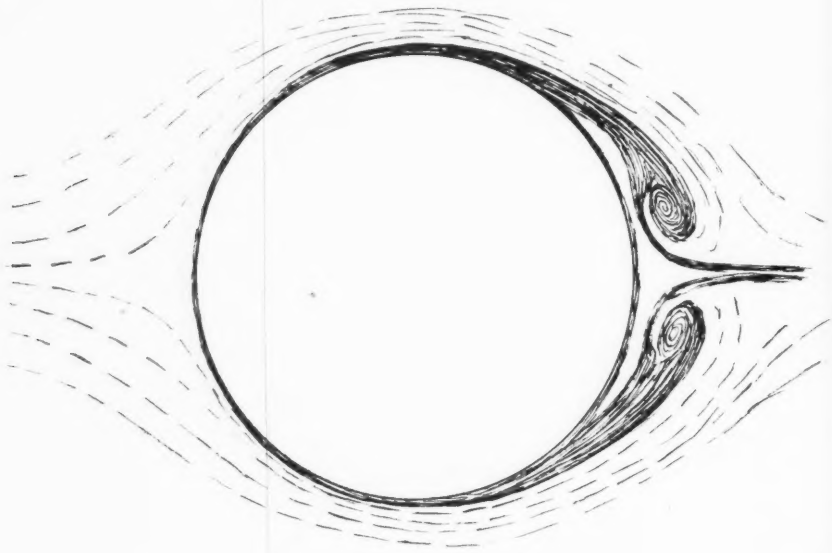


FIG. 6.

The direct action of the rotating cylinder in dragging the neighbouring fluid with it is held to have no effect in imparting circulation to the fluid as a whole in paths enclosing the cylinder. Thus the accumulation of retarded rotating fluid in the boundary layer and its detachment in masses, both being asymmetrical, is the only cause of effective circulation.

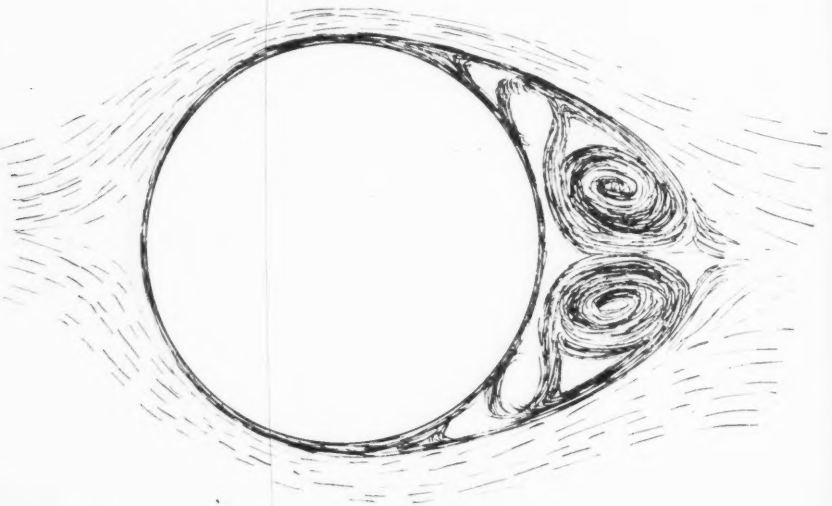


FIG. 7.

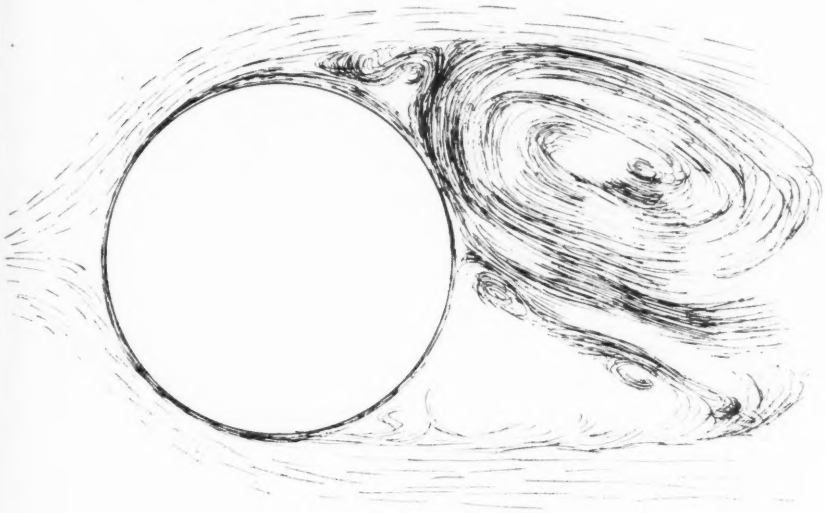


FIG. 8.

Two experiments are given in support of this view. When the accumulation of retarded fluid is sucked away as fast as it is formed by means of orifices in the surface of the cylinder, the formation and detachment of eddies is largely suppressed. Again, when the rotating cylinder is given linear motion an additional amount of work is done which is held to be equivalent to the energy of circulation.

It is better here to quote Prandtl's own statement, p. 105:—

"To dispel a widespread error it may be said that the kinetic energy due to the superposed circulation component has no connection with the dissipation of energy by air friction which the cylinder must make good.

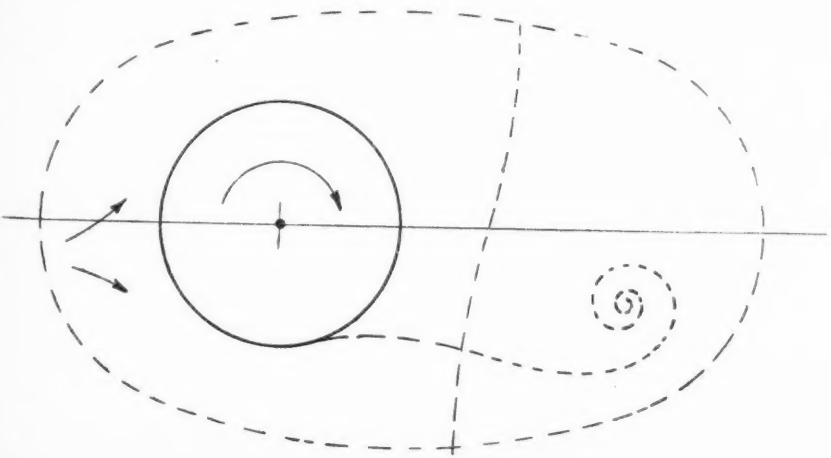


FIG. 9.

"As my collaborator, Dept. Ing. Akeret, has shown in a hitherto unpublished research, the cylinder during the building up of the circulation has overcome a resistance while it advances; the corresponding work done is the equivalent of the energy developed in the flow.

"If the cylinder has imposed on it an angular rotation such that its surface (aw) speed exceeds the maximum stream velocity without circulation ($2V$) the boundary layer is no longer retarded, but rather carried round by the cylinder and an increase in the detachment of vortices is no longer to be expected beyond this speed. . . .

"We conclude that in this case (1) the configuration of flow is reached where the two dead water points are coincident on the boundary; (2) the corresponding lift coefficient attains the maximum possible value. . . . The lift coefficient at this circulation is given by $C_a = 4\pi = 12.57$ and this is a maximum."*

To turn to other points, Prandtl finds that the poor lift given without end caps is due to centrifugal forces set up by the relatively high rotational speeds. In the original experiments a cylinder of four centimetres diameter extended nearly from wall to wall, a length of 20 cm., in a rectangular partition, the axis being 25 cm. from the bottom and 19 cm. from the top of the partition. These partitions acted as fixed end caps and by their retarding effect on the circulation component set up a current, flowing in at the end of the cylinders, of air which had lost its circulation velocity. The value of C_a obtained was only 4. By adding end caps of 8 cm. diameter, rotating with the cylinder, the lift coefficient was brought up to 10. These results have already been quoted from Flettner's paper, but Prandtl's conclusions are of interest.

He takes the figure 10 as a satisfactory approach to his theoretical maximum of 12.57, "since the losses due to friction prevent any expectation of reaching the full value."

"With regard to the possibility of application of rotating cylinders, discussions were held at the time of these experiments, but none of us saw any practical gain in such cases as were discussed—wings, propellers, windmills, turbine blades, etc. Till this day I have not altered my views. In comparison with wing-shaped structures, the application of rotating cylinders, with ten times the lift per unit surface, permit considerable reduction in fore and aft dimensions, but the advantage is lessened by the superiority of structures with no moving parts, and good wings have less drag. It is further to be noted that no reduction is possible in span or radius of arm in windmills, etc., since the limit of load in such apparatus depends on the amount of air dealt with per second.

"The application to sailing ships, where the conditions are quite different and offer great advantages to the rotating cylinder, unfortunately, did not come under discussion. This was reserved for Herr Autor Flettner, the well-known inventor of the Flettner ship's rudder."

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* It is seen that there is complete incompatibility between this explanation, and that suggested by the writer in the last article. The grounds of disagreement are wider than a particular result. The writer's explanation was not a guess hazarded at random, but was carefully constructed on the basis of views first stated by Kelvin, and developed by Riabouschinsky. There are, moreover, several difficulties raised by Prandtl's theory, some of which seem fundamental. The writer does not propose to go into detailed comment here, but rather to complete his views on the physical processes of fluid motion for statement later as a whole. The whole matter must remain somewhat speculative until many crucial experiments have been carried out.